TU Delft

Using Distributed Temperature Sensing for evaporation measurements

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Introduction

The conventional Bowen ratio surface energy balance method (BREB) for partitioning of fluxes needs multiple independent sensors, resulting in large measuring errors.

The BR-DTS method (*Euser et al., 2014*) uses a fibre optic cable to measure the dry and wet bulb temperature profile over the height at a high spatial resolution.

Using the dry and wet bulb temperature gradients the Bowen ratio can be calculated.

For the verification of the method, the cable temperatures are compared to air temperature sensors. The DTS-based Bowen ratio is compared to the eddy covariance based Bowen ratio, and the heat fluxes resulting from the Bowen ratio energy balance are compared to eddy covariance measurements.

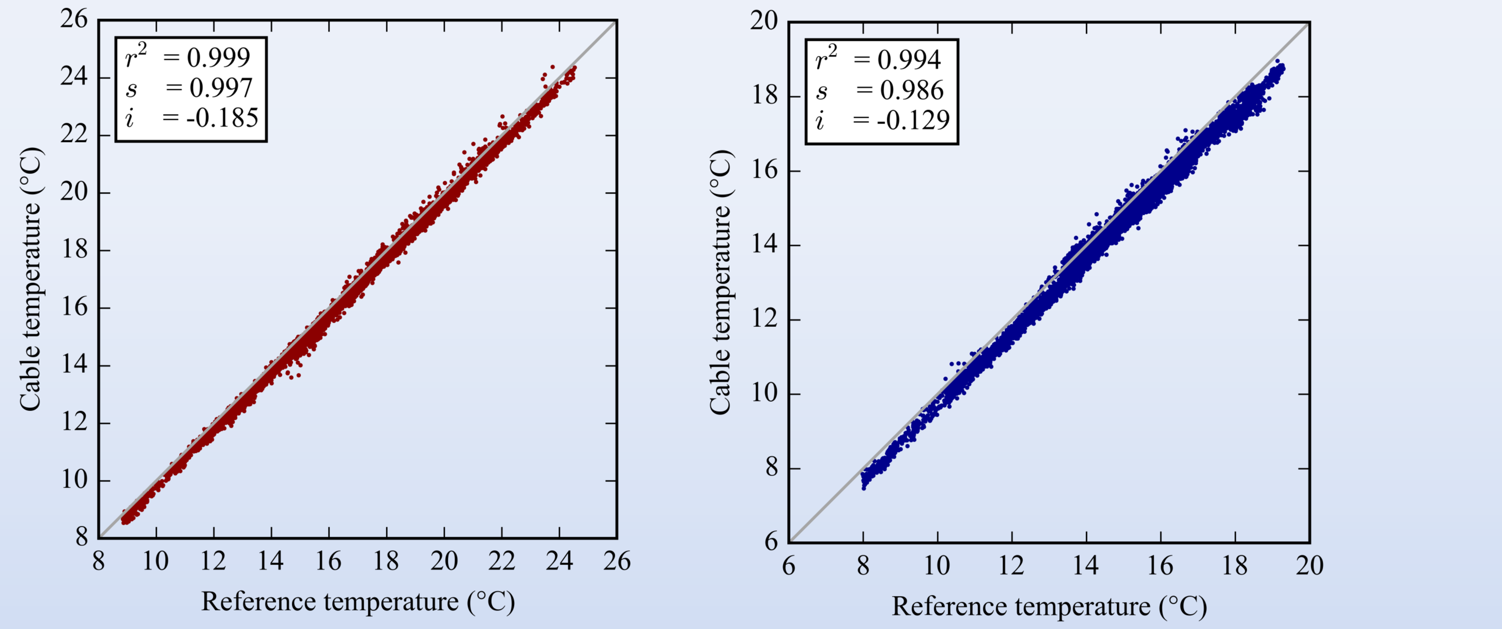
DTS?

Distributed Temperature Sensing is a technique where the temperature of a glass fibre optic cable is measured. It works by sending a laser pulse into the fibre optic cable and looking at the frequency spectrum of the light that is scattered back. Using this technique the temperature can be measured every second, at 25cm spatial resolution, for kilometres of cable.

The fibre optic cables can be suspended in air, water, or put into the ground, to measure high resolution temperature profiles.

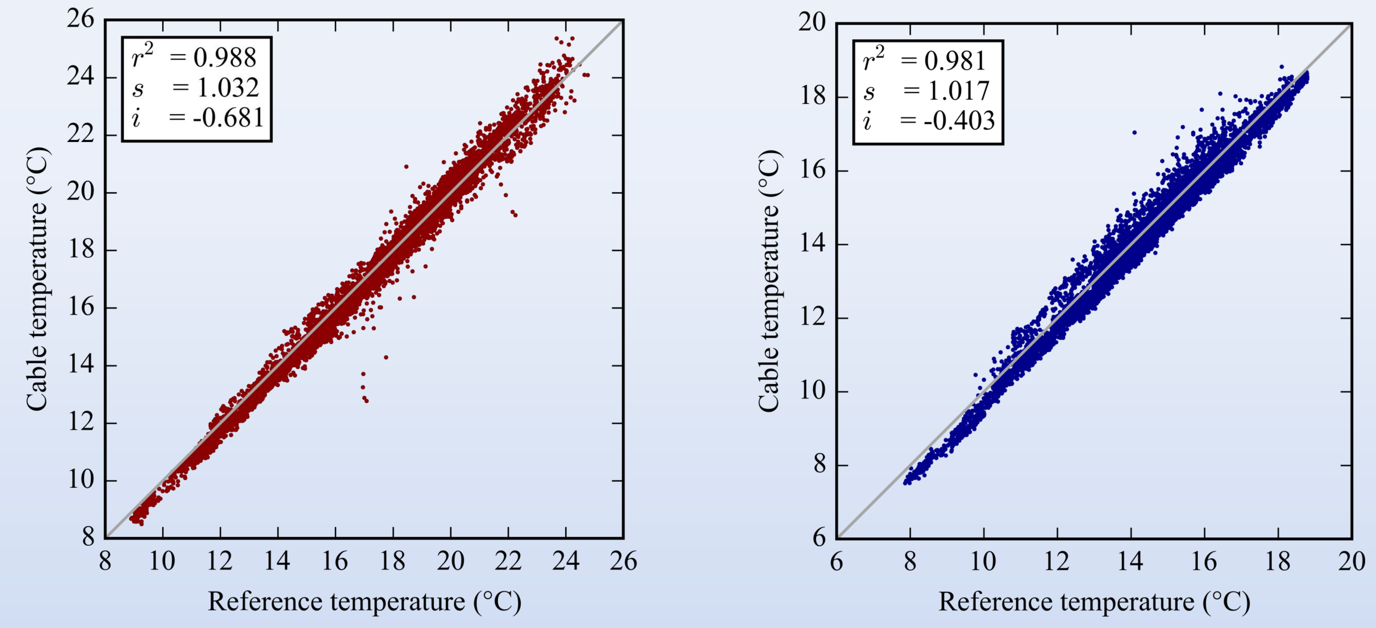
Temperature verification: Below canopy

Below the canopy the temperatures of the DTS and verification sensors were nearly the same. The wet bulb temperature was well represented by the wet cable, even as wind speeds were often very low (0 to 0.5 m s^{-1})



Temperature verification: Above canopy

Above the canopy, and shielded from direct sunlight by wire mesh screens, the DTS temperatures also correlate well with the reference sensors. Some influence from the solar radiation is still visible, but it is greatly reduced. The wet cable temperature seems more affected than the dry temperature.



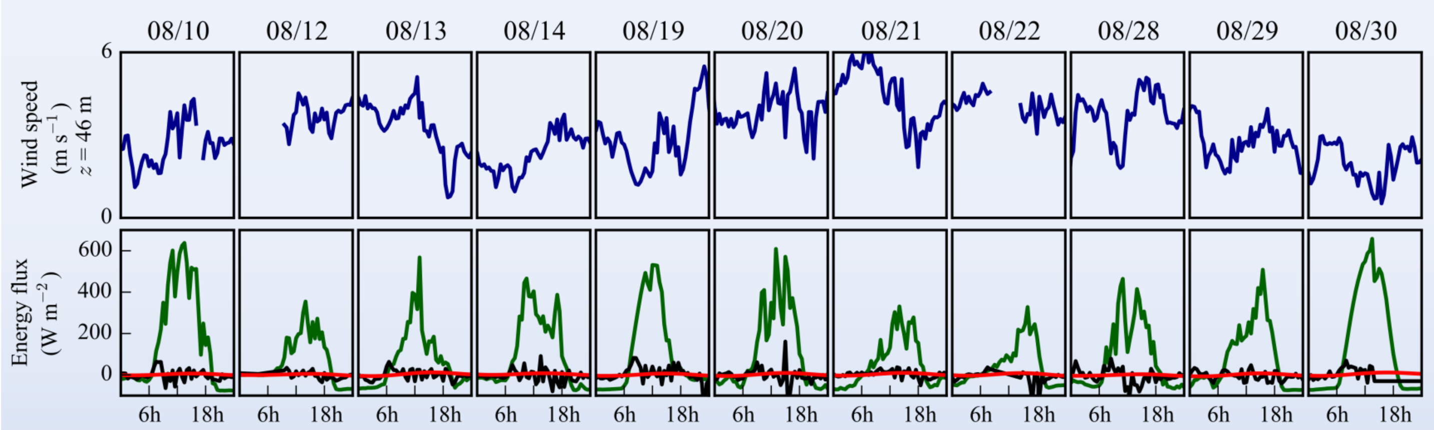
Materials & Methods

Measurements were done in a Douglas fir forest in the 'Speulderbos', in the Netherlands, at a 48m tall measurement tower. The DTS cable was vertically suspended along the height of the tower, and shielded from direct sunlight above the canopy.

To keep one stretch of DTS cable wet it is wrapped in cloth and supplied with water by a pump.

To determine the energy balance, the net radiation is measured at the top of the tower, and the soil heat flux is measured on the forest floor. The heat storage in the air column is calculated using the DTS based temperature profile. By combining the Bowen ratio and the energy balance, the latent heat and sensible heat fluxes are determined.

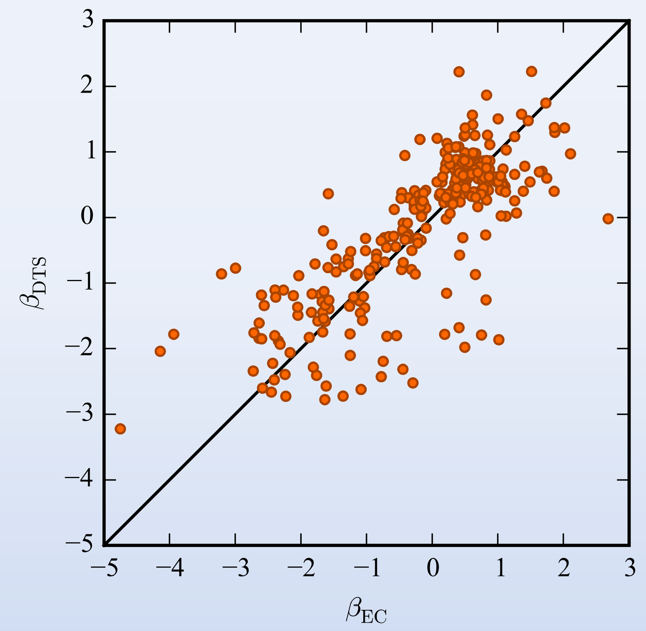
Wind speed and energy balance components



Green: Net radiation. *Red*: Soil heat flux. *Black*: Energy storage change

Bowen ratio comparison

The Bowen ratio as measured using DTS correlated well with eddy covariance data (R^2=0.59), at 15 minute averages.



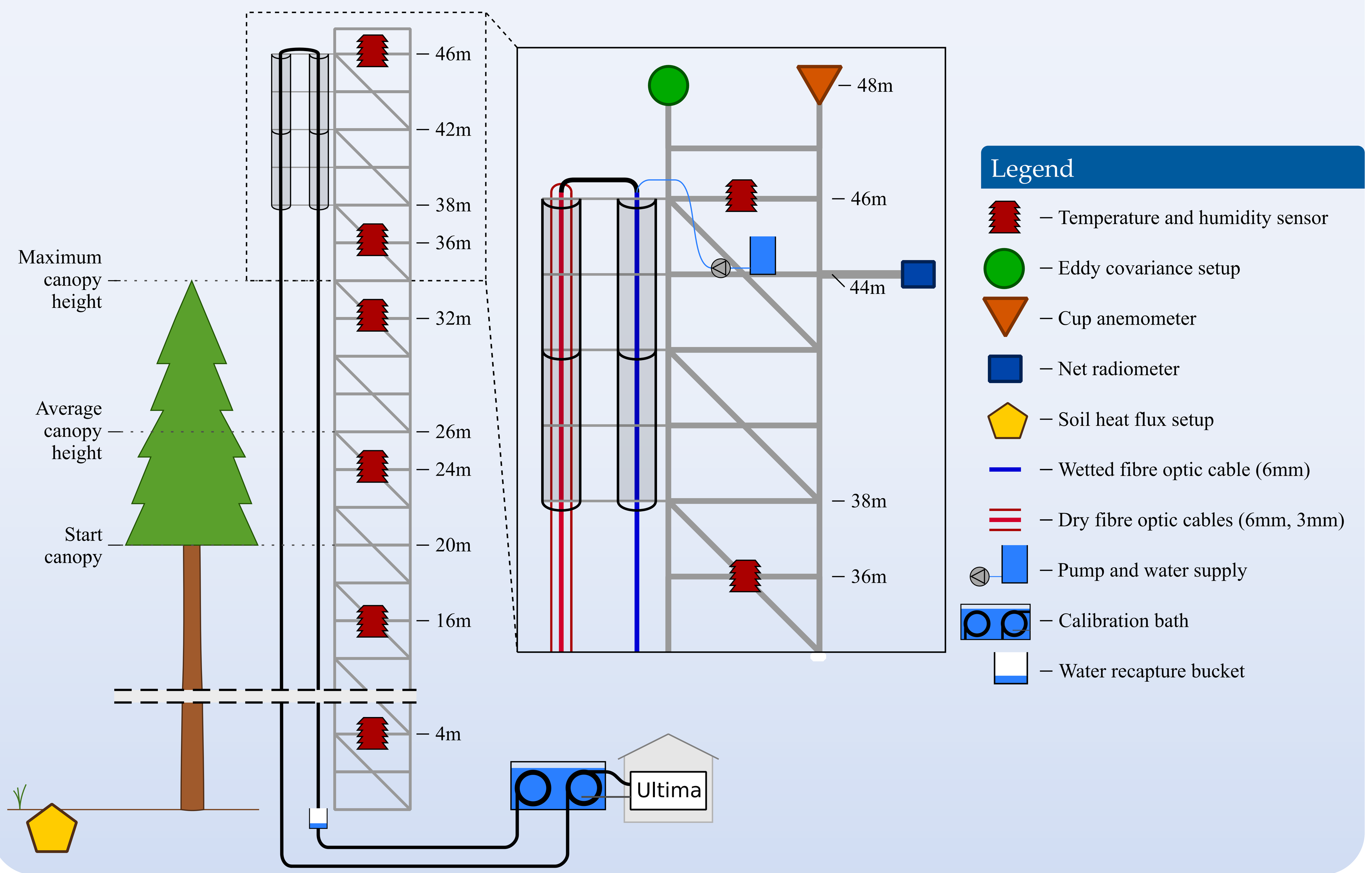
Flux-variance

The flux-variance method is a way to calculate the sensible heat flux using only temperature data. It is derived from Monin-Obukhov similarity theory and is valid during unstable atmospheric conditions. By having an independent estimate for H, combined with the Bowen ratio, the latent heat flux could be estimated using only DTS data. This method can already be applied to the sonic anemometer data, and gives a very good estimate for the sensible heat flux. To get similar results for the DTS data, a thin cable has to be used, and measured at high frequency.

$$H_{FV} = \rho c_p \left(\frac{\sigma_T}{C_1}\right)^{\frac{3}{2}} \left(\frac{\kappa g (z - d_0)}{\overline{T}}\right)^{\frac{1}{2}}$$

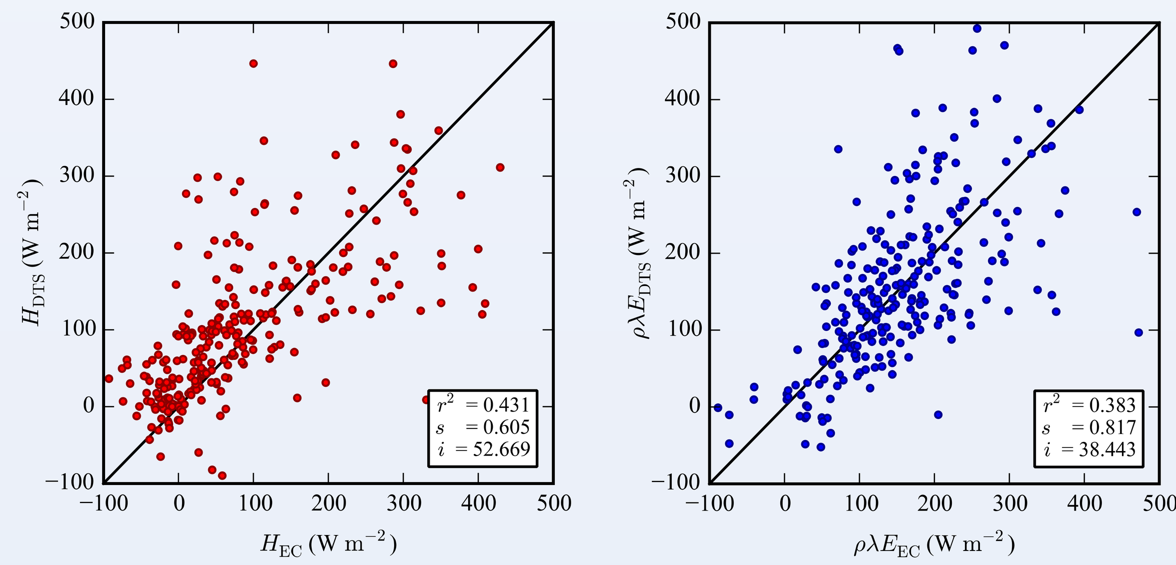
σ_T: standard deviation of temperature (K)
$\overline{T}$: mean air temperature (K)

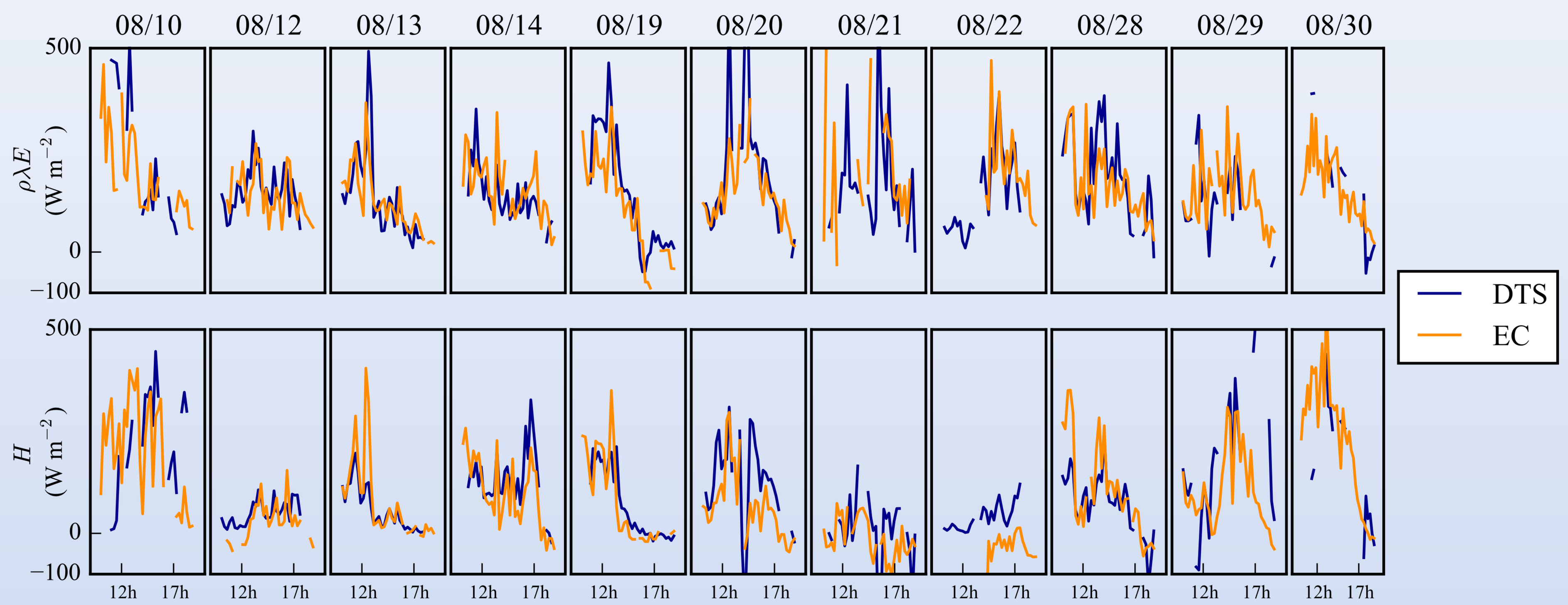
Measurement setup



Heat flux verification

When comparing the fluxes resulting from the BR-DTS method to eddy covariance, they were in agreement. However, very noisy. One of the reasons for the noisy data is that during the measurements the weather was changeable, with no completely clear sunny days.





Conclusions

The DTS measured air temperatures are nearly the same as the air temperature sensors, and the performance below the canopy was perfect. Above the canopy the cable temperatures were influenced by solar radiation, but the screens blocked most sunlight. The wet bulb temperature was approached well by the wet cable, and wind speed did not appear to be of a big influence.

The Bowen ratio resulting from the DTS temperature profiles was in agreement with the eddy covariance estimate, both at night and during daytime, despite the slightly different fetch due to the difference in measurement heights.

The fluxes of the Bowen ratio energy balance method were compared to the eddy covariance measured fluxes and are in agreement, although the correlation plots show a large amount of noise. However, these results show that even above a tall forest in a temperate climate, good estimates for the heat fluxes can be made using DTS.

Expanding on the DTS method for measuring evaporation by incorporating the flux-variance method seems promising, as it will be able to serve as either a check on the sensible heat flux, or even to use in calculating the evaporation using only DTS data.

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